

MicroTurbines



Capstone Development Efforts

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Agenda

- *Overview of Capstone Microturbine*
- *CHP development*
- *200 kW Microturbine
DOE funded development*
- *Planned products through collaboration
with UTC Power*

What is a microturbine and what does it do?

- *A microturbine is a turbine engine-generator, typically sized 250 kW or less*
- *Microturbines can efficiently supplement energy use at the point of use*
- *Creates electricity and heat*
 - *Similar to installing a furnace, boiler, backup genset or chiller*
- *About 3,000 microturbine have been shipped worldwide*



An array of 8 kerosene-fueled microturbine at a Japan hospital

What's in it for the customer?

- ***Reduce your facility's energy costs***
 - *Create energy onsite whenever economically advantageous*
 - *Minimize demand and other utility charges*
- ***Support energy conservation efforts***
- ***Reduce environmental impact***
 - *Offset higher emission utility power*
 - *Reduce flare emissions*
- ***Avoid power outages***
 - *Eliminate production and data losses*
 - *Provide power during emergencies*
 - *Isolate priority loads in problem areas*
- ***Solve facility power problems***
 - *Produce power where needed*
 - *Create power at remote sites*



Microturbines fueled by sewage gas

Applications: Cogeneration (“CHP/CCHP”)

Examples of high-efficiency CHP (combined heating and power) and CCHP (combined chilling, heating and power)

✓ **Direct exhaust**

✓ **Hot water**

✓ **Cooling**

Clockwise from top: microturbine exhaust directly fires a 20-ton chiller at Univ. of MD; exhaust from two microturbine fueled by oil flare gas direct heats oil/water separator; microturbine provide power and water/building heating at a YMCA.



Applications: Oilfield flare gas reduction



*Various oilfield
flare/casing gas
installations
onshore and
offshore*

- *Free/low-cost onsite fuel*
- *Generate onsite power from onsite waste or low-value gas*
- *Avoid electrification costs in remote areas*
- *Offset power bills in wired areas*
- *Destroy odors, methane and non-methane compounds*
- *Positive environmental impact*
 - *Avoid emissions penalty charges*
 - *Avoid emission-credit purchases*

Applications: Renewable Biogas

Several bio-fueled microturbine installations



Generate power and heat from flare gas at sewage plants, landfills, livestock farms, food waste, etc.



Applications: Standby, peak or prime power

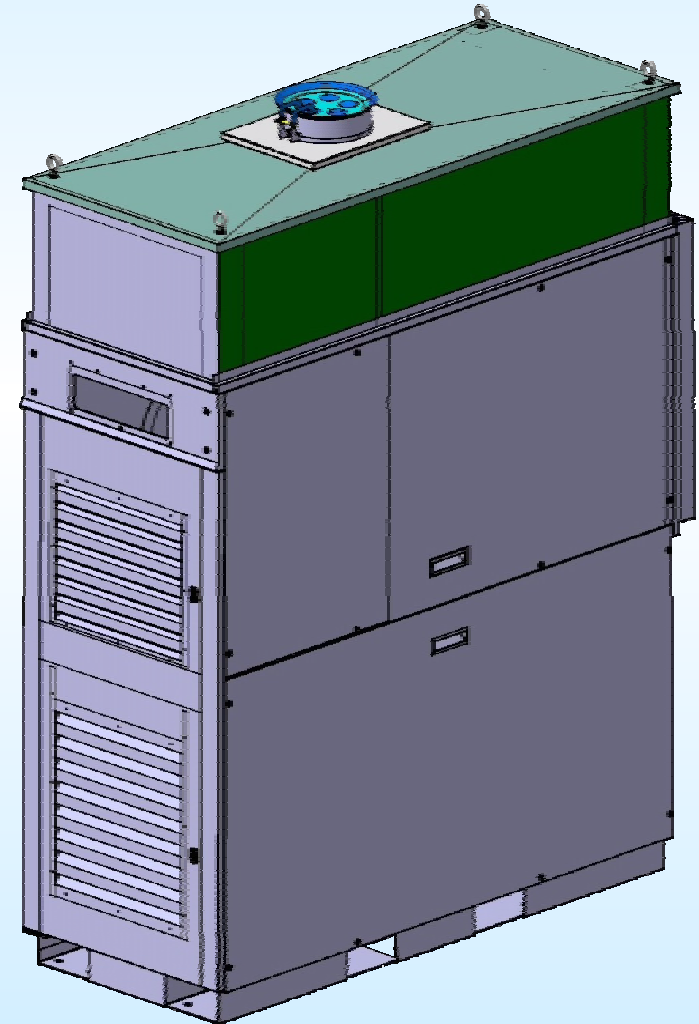
Ensure power certainty in remote areas and in critical business operations



Capstone's New Integrated C60 CHP System



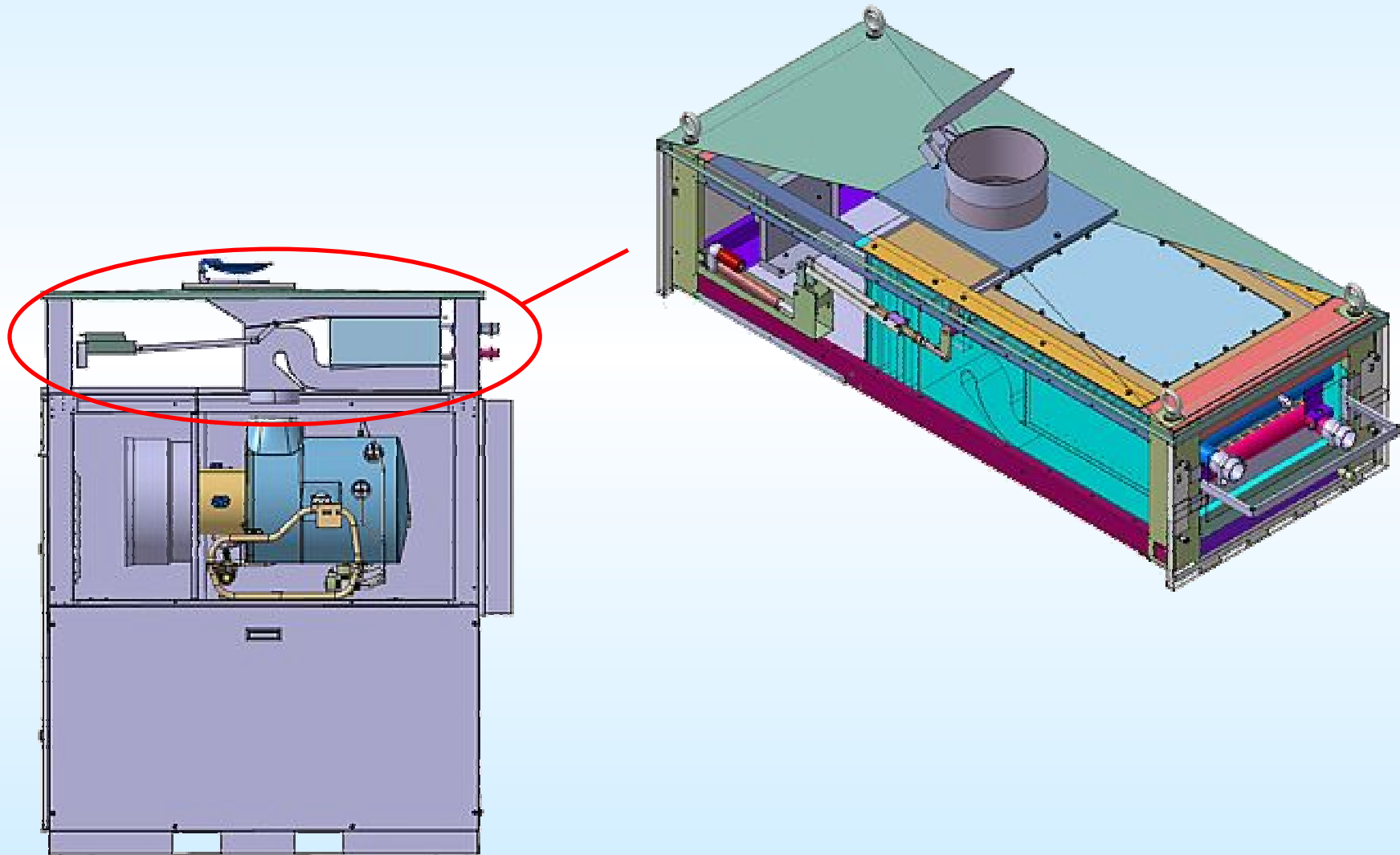
- *Overview of Features / Benefits*
- *Design Concept*
- *Heat Recovery Modes*



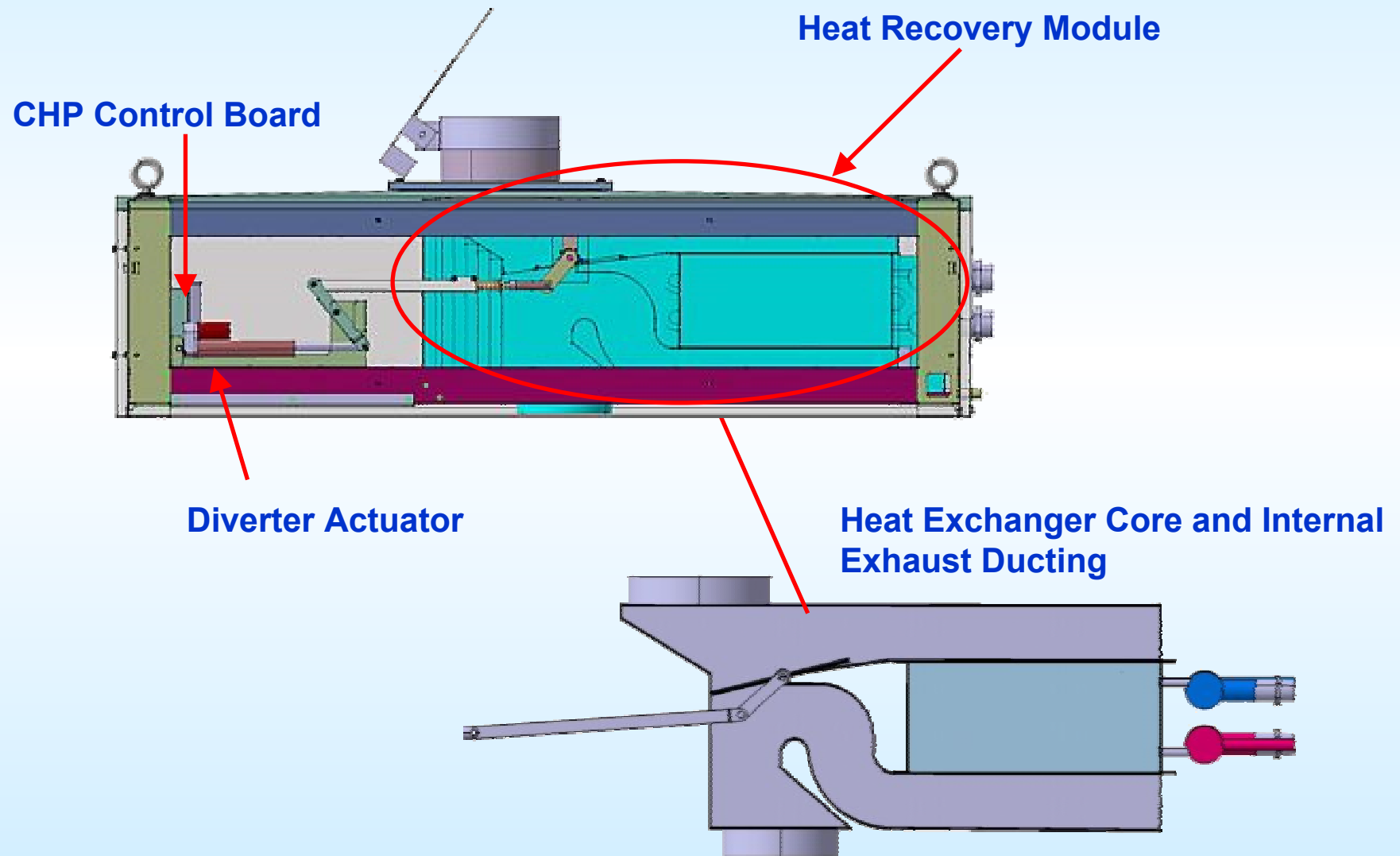
Features and Benefits

Feature	Benefit
Top Mount Heat Recovery Module	Requires Minimum Footprint
Two Heat Recovery Modes: 1. Thermal Priority 2. Electric Priority with Thermal Track	Useful for Many Different Heat Recovery Applications
Analog Inputs for Electric and Thermal Control	Simple Interface with Building or Process Control
Water Temperature, Status, and Setpoints read using Capstone C60 Display and CRMS	Eliminates Separate Temperature Metering and Provides Single User Interface
Entire CHP System is UL and CSA Listed	Facilitates local permitting

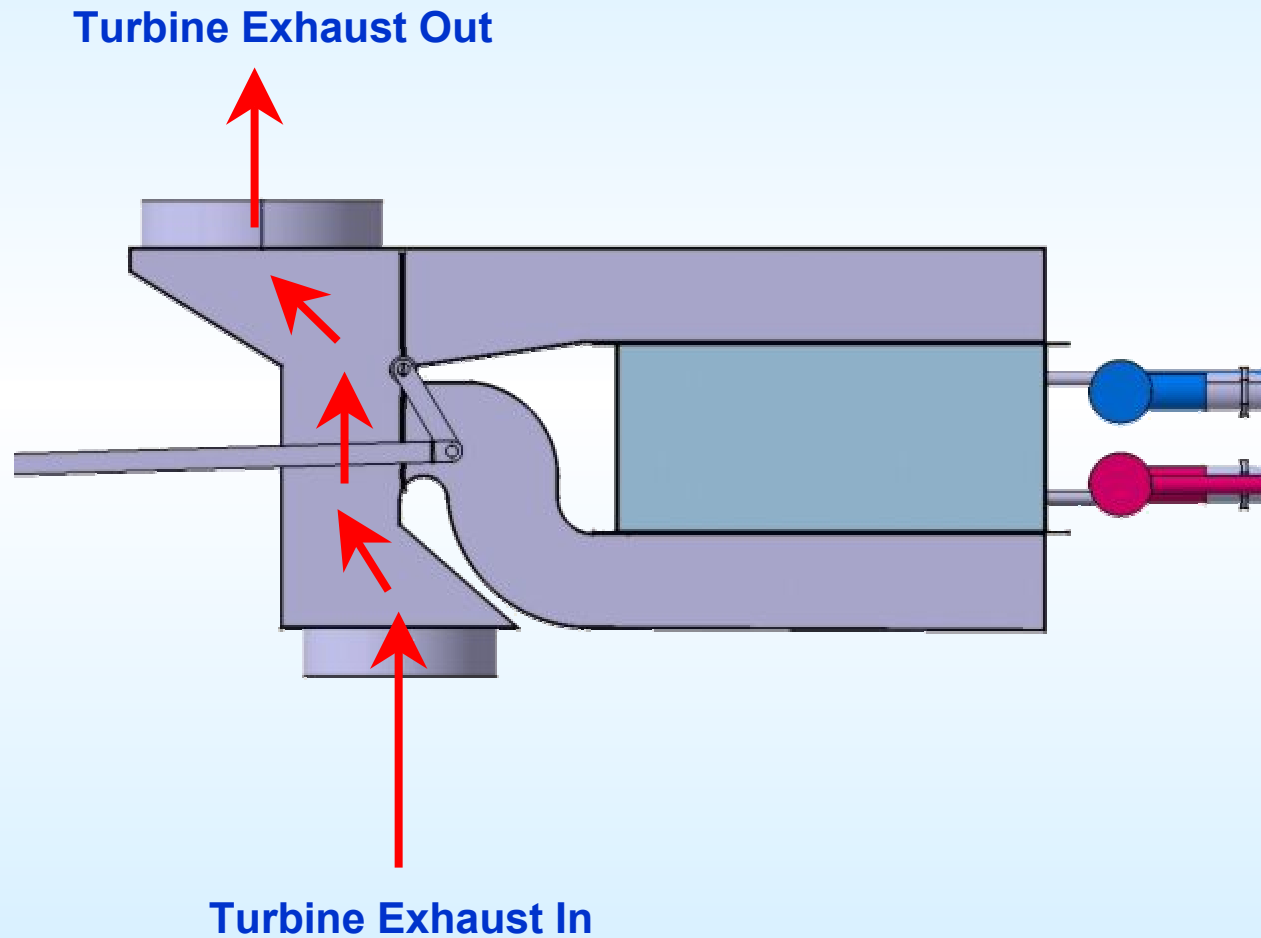
Heat Recovery Module Concept



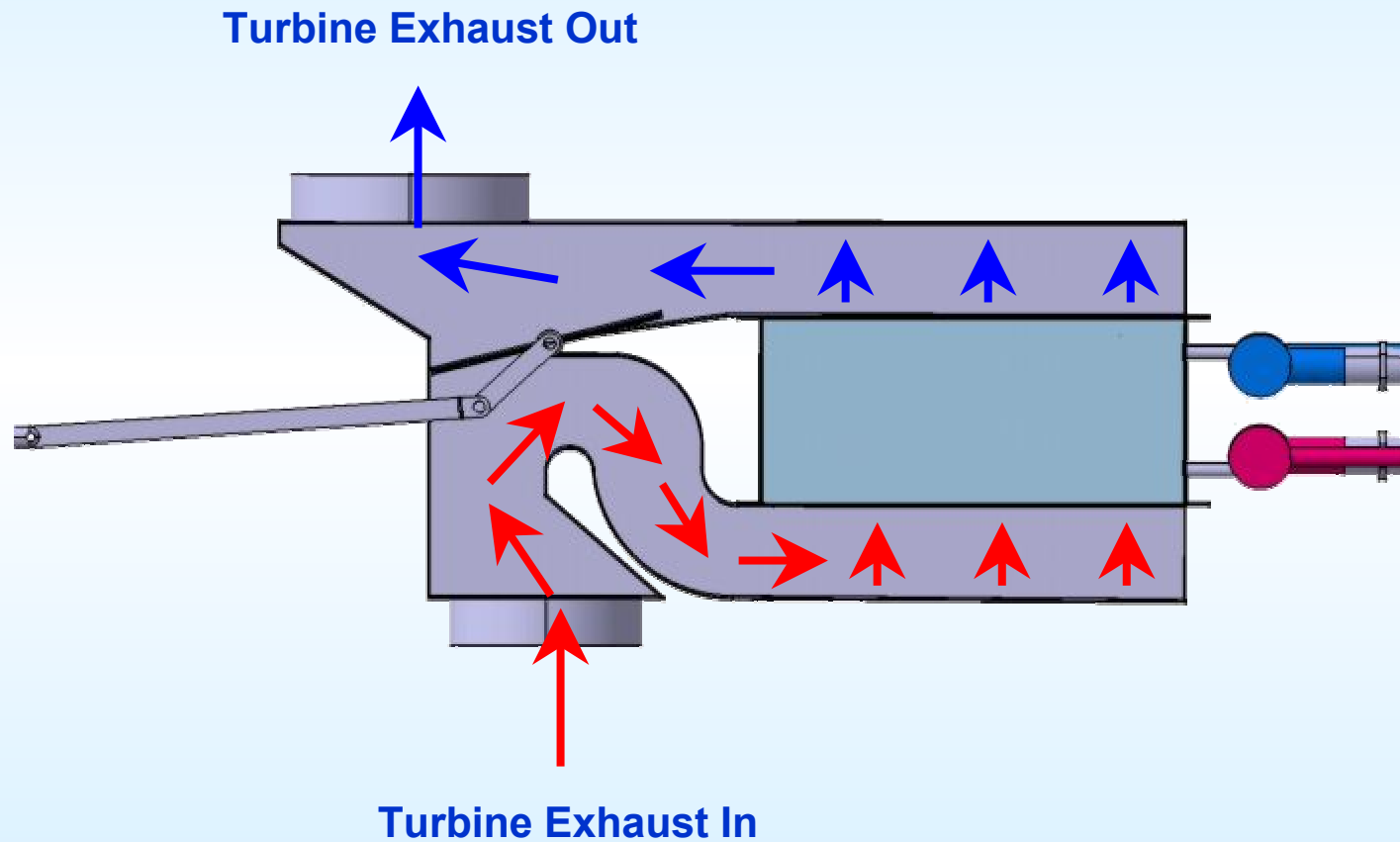
Heat Recovery Module Elements



Diverter in Bypass



Diverter In Heat Recovery



Modes of Heat Recovery

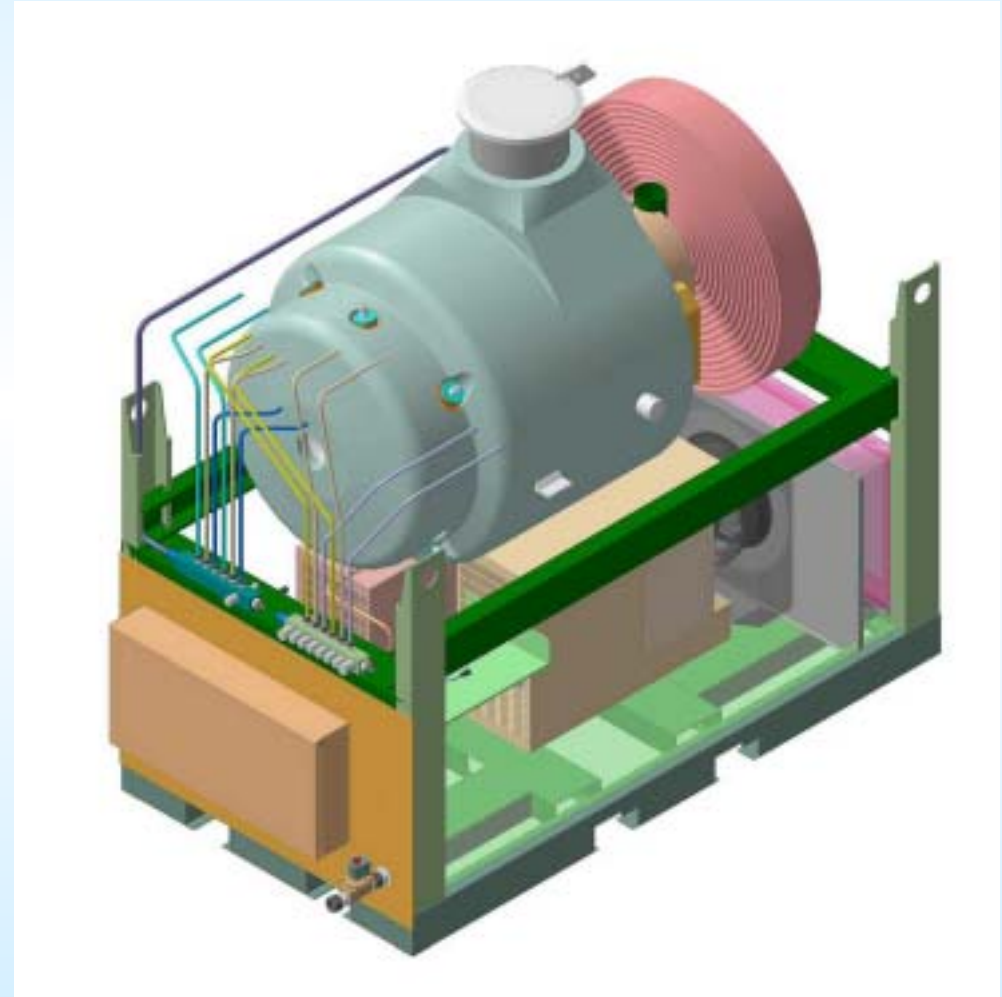
Mode	Description
Thermal Priority	Follows requested heat recovery. Electric power is automatically adjusted to provide thermal.
Electric Priority with Thermal Tracking	Electric power is controlled. The diverter is adjusted to try to maintain the measured water outlet temperature.

C200 Microturbine Development

- ***Topics***
 - ***System Characteristics***
 - ***Engine and Recuperator Development***
 - ***Testing***
- ***Support by funding for the DOE Advanced Microturbine Program***
 - ***Goals: 40% efficiency, \$500/kW, 7 ppm NOx, multiple fuels, 45k hour life***

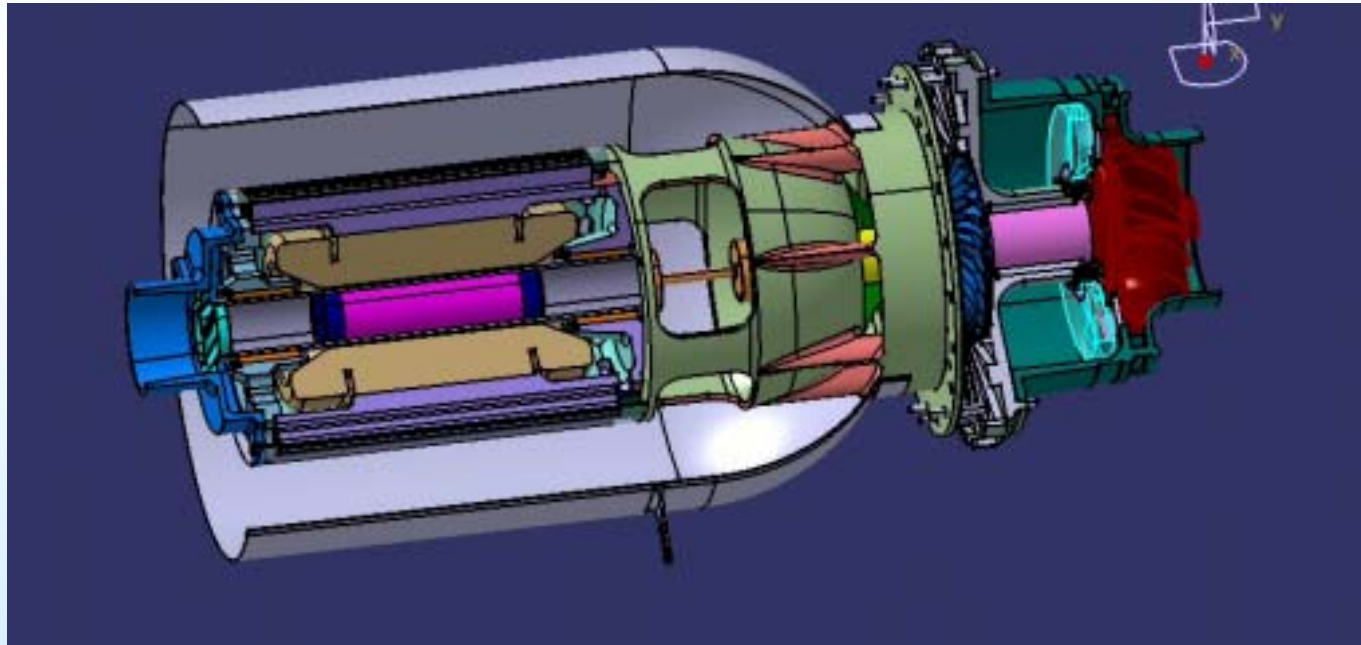
C200 System Characteristics

- ***Leverage experience from past microturbine development***
- ***Annular recuperator***
- ***Annular low emission combustion system***
- ***IGBT based power electronics***



C200 Engine

- *High speed air-cooled generator*
- *Single stage centrifugal compressor*
- *Single stage radial inflow turbine*
- *Air bearings*
- *Single shaft*

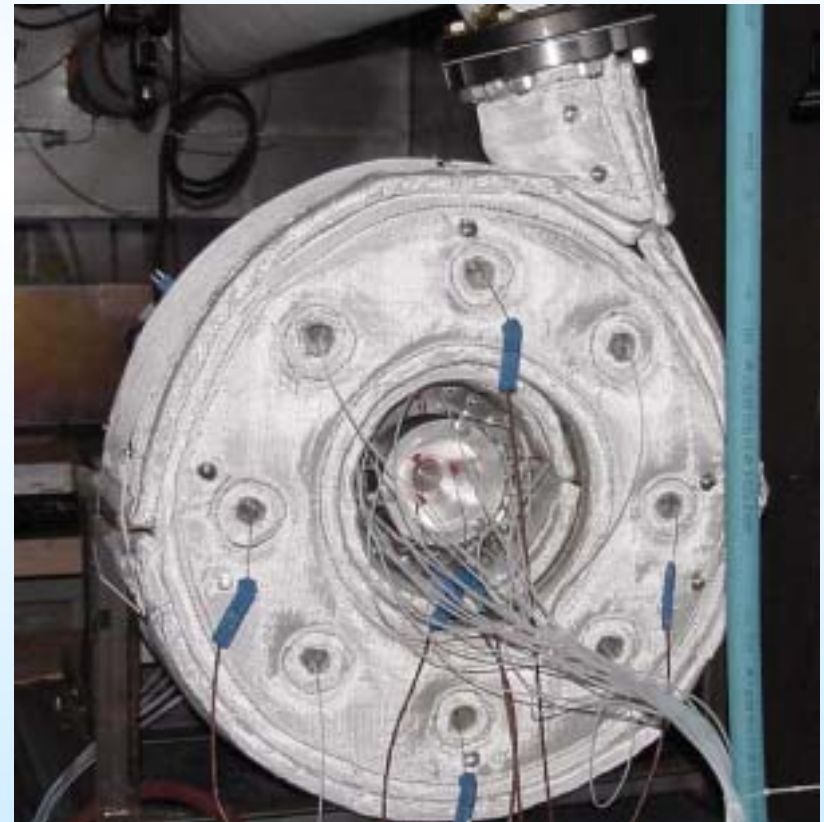


Expected Performance

Rated Power	200 kW
Net Efficiency (HP-ISO)	34-35%
TET	1185 °F (640 °C)
Pressure Ratio	4:1
Emissions	Meets CA 2003
Overhaul life	40,000 hours

Development Rigs

- ***Used to develop components***
- ***Reduces development risk***
- ***Bearings and rotordynamic***
- ***Compressor***
- ***Combustor***



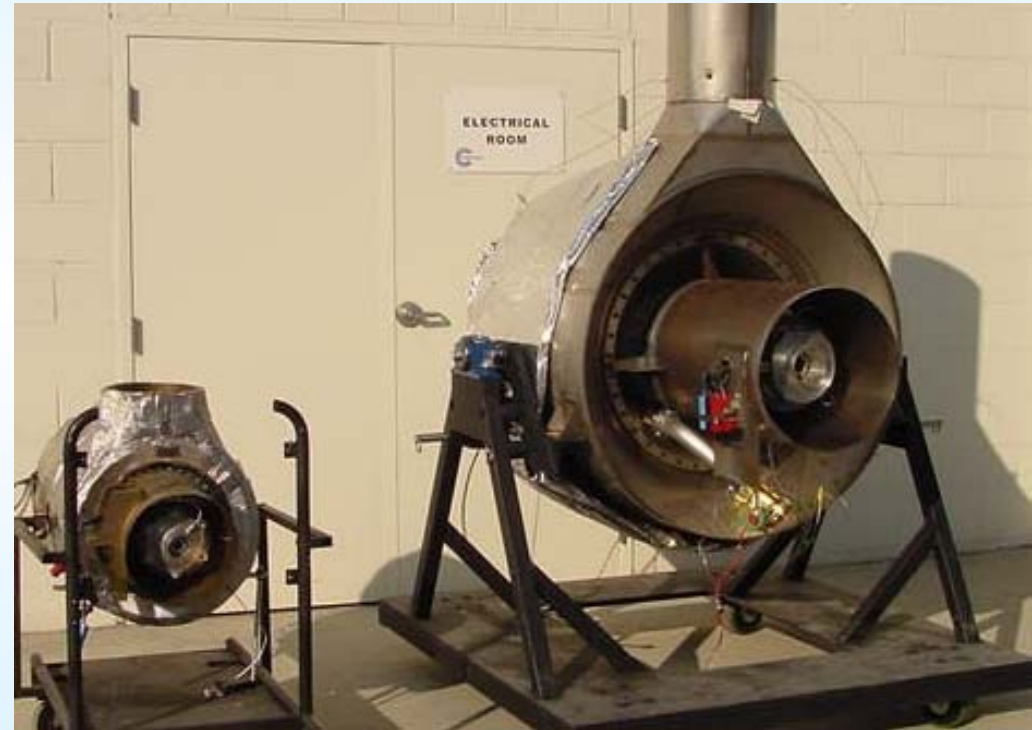
C200 Recuperator Development

- *Internally designed heat transfer surfaces and mechanical configuration*
- *Meets effectiveness and pressure drop requirements*
- *Mechanical design focused on manufacturability (few parts, superior welding geometry)*
- *Significant CFD to optimize performance*
- *Rig testing of full size segments to characterize performance and manufacturing*
- *First core produced 11/02*



Engine Testing

- ***First engine operation 9/02 (simple cycle)***
- ***First recuperated engine operation 12/02***
- ***Performance of system on target***
- ***Engine endurance testing initiated***
- ***NOx emissions on target***



Expected Efforts

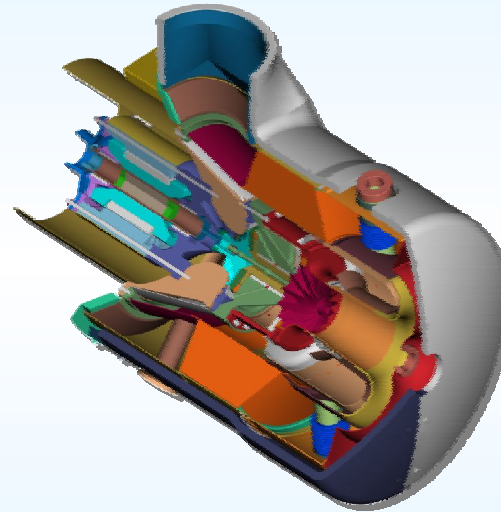
- ***Complete engine endurance testing***
- ***System integration***
- ***Product release testing***
- ***Beta testing***
- ***Commercial release – 2004***

UTC and Capstone working together

- **UTC and Capstone have entered into a strategic alliance**
- **UTC Power will distribute Capstone products**
- **UTC**
 - **Strong established sales and service organization**
 - **Integrated applications that leverage *UTC's* expertise in CHP and cooling**
- ***Capstone***
 - ***Leader in microturbine and distributed generation***

UTC POWER MICROTURBINE

Gas Turbine Engine



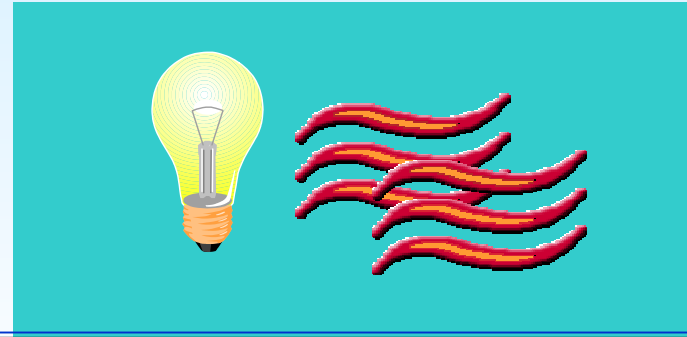
- ***Proven technology***
- ***Low emissions***

UTC MICROTURBINE

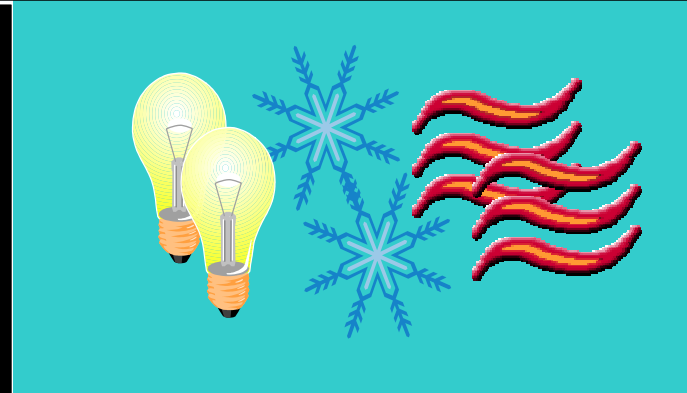
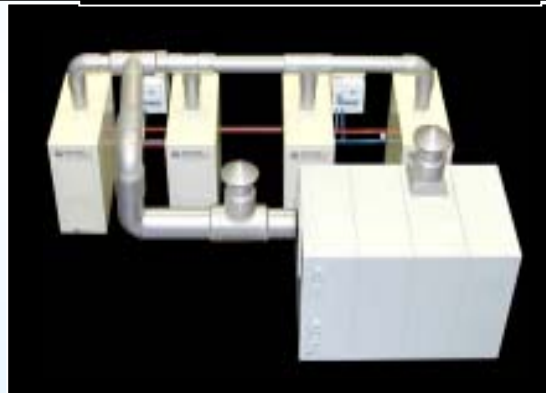
Applications – Integrated Systems

Electric Energy Requirements

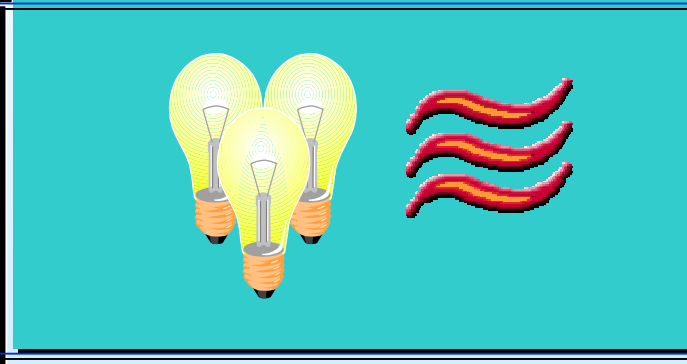
Heat & Power Solution
60kW – 1MW+



Chiller/Heater Solution
240kW – 1MW+



Power & Heat Solution
300kW – 1MW+



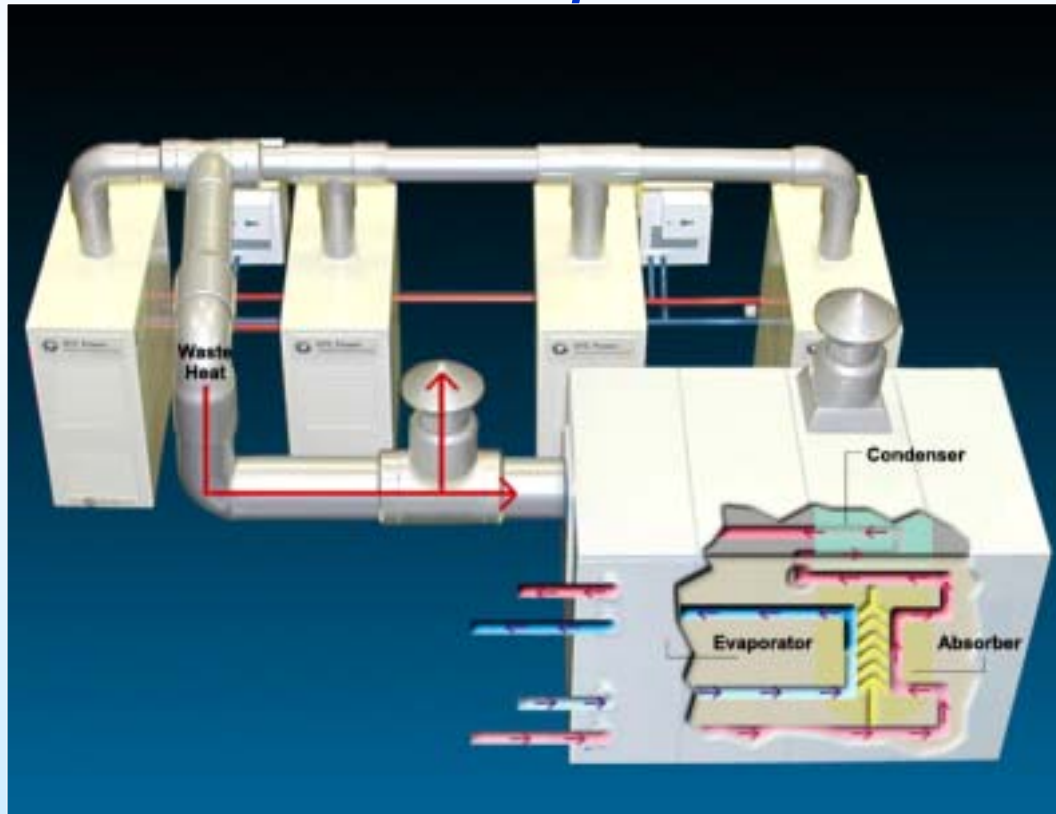
UTC CHILLER/HEATER SOLUTION

Provides:

~ 240 kW Electrical Power

~ 118 tons of chilled water

~ 270 kW Hot Water up to 175° F



Double-effect chiller/heater

✓ **Allows year-round benefits**

No fluorocarbons

✓ **contributes to NY State tax credit**

Ideal for buildings with chilled water systems:

- **High rise apartments**
- **Office Buildings**
- **Hospitals**
- **Hotels**

UTC POWER & HEAT SOLUTION

Provides:

~ 300 kW Electrical Power

~ 170 kW Hot Water up to 220° F



*Ideal for high electric to
thermal load buildings:*

- *Office*
- *Retail*
- *Government*
- *Manufacturing*

Thank You